WHAT IS CLAIMED IS:

1. A method of detecting three-dimensional information, comprising steps of:

forming an image of an object illuminated by illumination light having given intensity as an optical image; and

detecting a distance between individual points of the object on the basis of an image obtained by acquisition of the optical image with a given image pick-up gain, wherein either the given intensity or the image pick-up gain is changed with time, and the distance between respective points of the object can be detected at a speed at which three-dimensional information can be followed real time within a period of time corresponding to the frame of a video signal.

2. The method of detecting three-dimensional information as defined in claim 1, wherein first and second optical images of the object illuminated by first and second illumination light, either of which includes time-varying intensity, are formed; first and second images are obtained by acquiring the first and second optical images with a single image pick-up gain over a given period of time; and the distance between respective points of the object can be detected on the basis of the first and second images at a speed at which the three-dimensional information can be followed real time within a period of time corresponding to the frame of a video signal.

3. The method of detecting three-dimensional information as defined in claim 2, wherein the intensity of the first illumination light is increased or decreased with time, and the second illumination light has a given intensity.

4. The method of detecting three-dimensional information as defined in claim 2, wherein the intensity of the first illumination light is increased with time, and the second illumination light is decreased with time.

5. The method of detecting three-dimensional information as defined in claim 1, wherein there are formed first and second optical images of the object illuminated by first and second illumination light which illuminate with single intensity over a predetermined period of time; and the distance between respective points of the object is detected from the first and second images which are produced by acquisition of the first and second optical images with the first and second image pick-up gains, either of which is changed with time, at a speed at which the three-dimensional information can be followed real time within a period of time corresponding to the frame of a video signal.

6. The method of detecting three-dimensional information as defined in claim 5, wherein the first image pick-up gain is increased or decreased with time, and the second image pick-up gain is uniform.

7. The method of detecting three-dimensional information as defined in claim 5, wherein the first image pick-up gain is increased with time, and the second image pick-up gain is decreased with time.

8. The method of detecting three-dimensional information as defined in any one of claims 1 through 7, wherein the image is acquired a plurality of times within a period of time corresponding to the frame of a video signal.

9. A device for detecting three-dimensional information pertaining to an object comprising:

a projection section capable of projecting illumination light having given intensity on the object;

an image pick-up section capable of acquiring an image of the object with a given image pick-up gain; and

a signal processing section which calculates the distance between respective points of the object on the basis of intensity level information included in a video signal output from the image pick-up section, wherein either the given intensity or the image pick-up gain is changed with time, and the distance between respective points of the object can be detected at a speed at which the three-dimensional information can be followed real time within a period of time corresponding to the frame of a video signal.

10. The device for detecting three-dimensional information as defined in claim 9, wherein the projection section is equipped with a light-emitting element whose light can be modulated in accordance with an electric signal.

11. The device for detecting three-dimensional information as defined in claim 9, wherein the projection section comprises a light-emitting element, and a modulator capable of modulating light emitted from the light-emitting element.

12. The device for detecting three-dimensional information as defined in claim 9, wherein the image pick-up section comprises:

imaging means for producing an optical image upon receipt of light reflected from the object;

an image pick-up element which captures the optical image and outputs a video signal; and

an image intensifier with gating operation which is disposed between the imaging means and the image pick-up element and which can control an image pick-up gain.

13. The device for detecting three-dimensional information as defined in claim 9, wherein the signal processing section calculates the distance between respective points of the object according to the method defined in any one of claims 2 through 8.

ABSTRACT OF THE DISCLOSURE

It is an object of the present invention to provide a method and apparatus which can be applied for acquiring a three-dimensional image of an object and detect three-dimensional information pertaining to the object real time within a period of time corresponding to the frame of a video signal.

[Means for Achieving the Object] An image of an object illuminated by illumination light having given intensity is formed as an optical image. The distance between respective points of the object is determined on the basis of a video which is obtained by acquiring the optical image with a given image pick-up gain. Here, either the intensity of the illumination light or the image pick-up gain is changed with time. The distribution of intensity of the image acquired by utilization of such intensity or image pick-up gain reflects a time lag between the time at which the illumination light is emitted from a light source and the time at which the light reflected from individual points of the object reaches an image pick-up device. The distribution of intensity includes information pertaining to the distance between the light source and the respective points of the object. The present invention enables detection of three-dimensional information at a speed at which the three-dimensional information can be followed real time within a period of time corresponding to the frame of the video signal.

[Characteristic Drawing] FIG. 1

[DOCUMENT NAME] DRAWINGS

[FIG. 1]

OBJECT

1 SIGNAL GENERATION SECTION

7 SIGNAL PROCESSING SECTION

10 PROJECTION SECTION

11 IMAGE PICK-UP SECTION

S1 ILLUMINATION LIGHT MODULATION SIGNAL

S2 IMAGE PICK-UP GAIN MODULATION SIGNAL

S3 CONTROL SIGNAL

S5 THREE-DIMENSIONAL INFORMATION SIGNAL

S6 ILLUMINATION LIGHT

S7 REFLECTED LIGHT

S41, S42 VIDEO SIGNAL

[FIG. 8]

LIGHT-EMITTING ELEMENT

S1 ILLUMINATION LIGHT MODULATION SIGNAL

S6 ILLUMINATION LIGHT

10A PROJECTION SECTION

30 ILLUMINATION OPTICAL SYSTEM

[FIG. 9]

10B PROJECTION SECTION

S1 ILLUMINATION LIGHT MODULATION SIGNAL

S3 LIGHT-EMITTING ELEMENT

S6 ILLUMINATION LIGHT

30 ILLUMINATION OPTICAL SYSTEM

33 LIGHT-EMITTING ELEMENT

34 FIXED LIGHT

[FIG. 10]

4 LENS

5 IMAGE INTENSIFIER WITH GATING OPERATION

6 IMAGE PICK-UP ELEMENT

11 IMAGE PICK-UP SECTION

20 OPTICAL IMAGE TRANSFER OPTICAL SYSTEM

21 GATE

22 IMAGE SPLIT CIRCUIT

S2 IMAGE PICK-UP GAIN MODULATION SIGNAL

S3 CONTROL SIGNAL

S7 LIGHT REFLECTED FROM OBJECT

S41 VIDEO SIGNAL

S42 VIDEO SIGNAL

[FIG. 11]

7 SIGNAL PROCESSING SECTION

41 SYNCHRONOUS SEPARATION CIRCUIT

42 IMAGE PICK-UP LEVEL STORAGE CIRCUIT 1

43 IMAGE PICK-UP LEVEL STORAGE CIRCUIT 2

44 COMPUTATION CIRCUIT

45 STORAGE CIRCUIT

46 SYNCHRONOUS SIGNAL ADDITION CIRCUIT

S3 CONTROL SIGNAL

S5 THREE-DIMENSIONAL INFORMATION SIGNAL

S41 AND S42 VIDEO SIGNAL

S47 SYNCHRONOUS PHASE CONTROL CIRCUIT

[FIG. 12]

PULSE LASER

HALF-MIRROR

REFLECTED PULSE

OBJECT

STOP

START

TIME-COUNT CIRCUIT

TIME DURING WHICH LASER BEAM TRAVELS

START

STOP

TIME DURING WHICH THE LASER BEAM TRAVELS BACK AND FORTH, DISTANCE

LASER (CONTINUOUS WAVE)

AMPLITUDE MODULATION

REFLECTED LIGHT

OBJECT

OSCILLATION CIRCUIT

PHASE-DIFFERENCE DETECTION CIRCUIT

TIME DURING WHICH LASER BEAM TRAVELS

TRANSMITTED LASER BEAM

RECEIVED LASER BEAM

PHASE DIFFERENCE (AFTER THE LASER BEAM HAS TRAVELED BACK AND FORTH), DISTANCE

[FIG. 13]

PULSE LASER BEAM

COLLIMATOR

BEAM SCANNER

TARGET

COLLIMATOR

PHOTO-MULTIPLEXER

CONSTANT-RATIO THRESHOLD VALUE CIRCUIT

STOP

TIME-TO-PULSE-HEIGHT CONVERTER

START

AVERAGING CIRCUIT

AD CONVERTER INTERFACE

BEAM SCANNER INTERFACE

COMPUTER

TARGET

9 MHz OSCILLATOR

15 mW HeNe LASER

OPTICAL MODULATOR

BEAM SPLITTER

SCANNER MOTOR

PHOTO-MULTIPLEXER

9 MHz FILTER

NETWORK ANALYZER

AMPLITUDE

PHASE

computer

[FIG. 14]

9 TV CAMERA

41 SINUSOIDAL WAVEFORM OSCILLATOR

42A PHASE CONTROL

42B PHASE CONTROL

43A AMPLIFICATION

43B AMPLIFICATION

44 DC POWER

45 SUPERIMPOSING RF SIGNAL ONTO VIDEO SIGNAL

46 WAVEFORM SHAPING

47 FREQUENCY-DIVISION AND DELAY

48 SETTING OF GATE WIDTH

[DESCRIPTION OF THE REFERENCE NUMERALS]

1 OBJECT

2 LASER BEAM

3 IMAGE INTENSIFIER TUBE

31 PHOTO-ELECTRIC SURFACE

32 FIBER OPTICAL PLATE

33 LIGHT RECEIVING SURFACE

41 SINUSOIDAL WAVE GENERATION CIRCUIT

42 PHASE CONTROL CIRCUIT

43 AMPLIFIER

44 DC POWER CIRCUIT

45 RF SIGNAL SUPERIMPOSING CIRCUIT

46 WAVEFORM SHAPING CIRCUIT

47 FREQUENCY-DIVISION AND DELAY CIRCUIT

48 GATE WIDTH SETTING CIRCUIT

49 MCP GATE DRIVE CIRCUIT